New Measurement of Interfacial Stress in Ag/Ni Multilayers

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Abstract No. Fong7999
Beamline: **X22C**

Two important thermodynamic quantities in the study of solid interfaces are the interface energy and the interface stress [1]. Several previous studies have reported that the (111) Ag/Ni interface stress is negative [2-4]. This implies that the interfaces push out, in contradiction with embedded atom method calculations [1]. There is a controversy over whether the experimental result is correct and it has been suggested that intermixing may explain the discrepancy [5]. We have begun a detailed study of the structure of Ag/Ni multilayers in an attempt to answer these questions.

Ag/Ni multilayers with bilayer repeat lengths varying from ~3 to 23 nm were deposited by ion beam sputtering onto Si (001) substrates that were kept at –190 $^{\circ}$C during deposition. In order to minimize the strong correlations in a structure refinement between the composition and the strain modulations, x-ray reflectivity measurements were made at energies of E=8.02 keV and 8.32 keV, which results in a large change in f' for Ni. The reflectivity data were refined using the SUPREX program [6].

The superlattice reflections around the (111) and (222) are shown for a 3.2 nm sample in Figures 1 and 2. The upper and lower curves in each graph refer to E=8.32 keV and 8.02 keV, respectively. SUPREX allows for a number of options in the modeling of the superlattice, but in order to fit the higher harmonics around the (111) and (222) it is necessary to include large strain gradients in both the Ag and Ni layers. Similar results were found for samples with larger bilayer repeat lengths. Models based on intermixing of the Ag and Ni layers do not fit the data. Glancing incidence measurements were used with substrate curvature measurements to determine the interface stress. The results are consistent with previous studies, and they suggest that the strain gradients may result from the formation of partially coherent interfaces which in turn are likely related to the compressive value of the interface stress.

Figure 1

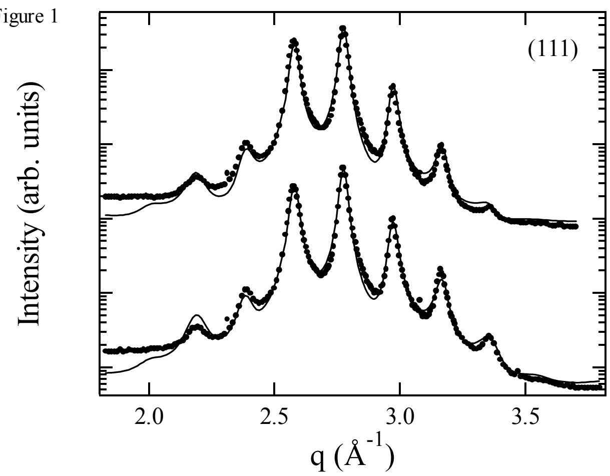
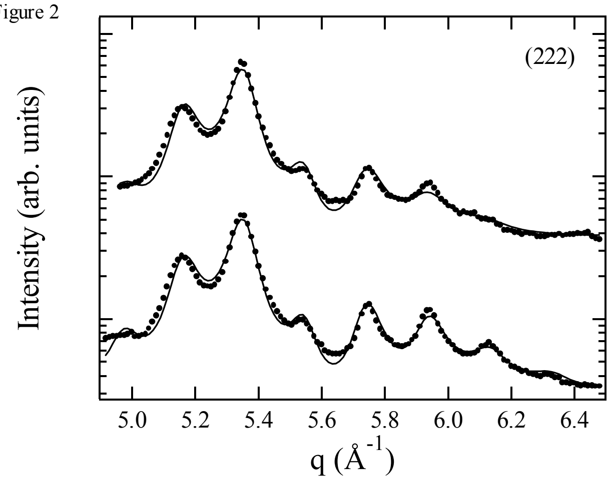


Figure 2



Acknowledgments: Support at Harvard University is from NSF through the Harvard MRSEC, under contract DMR98-09363.

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